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REVIEW

Improving the assessment of invasive alien species threat through integration of social dimensions in risk analysis

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Abstract Biological invasions are intertwined with social practices since they stem from human activities and behaviours. Hence, social, political and historical contexts are critical to inform effective actions for the management of invasive alien species (IAS). We argue that an IAS risk analysis which considers and includes the social dimensions can foster the application of measures and research across scales. Thus, this systematic literature review examines the trends of social dimension in IAS studies and investigates their potential to inform the risk analysis components. We analysed 378 publications on IAS incorporating social dimensions (197 peer-reviewed and 181 media articles) to understand their potential to inform three key risk analysis components, i.e., risk assessment, risk management, and risk communication. The review reveals a growing trend in the inclusion of the social dimensions in IAS research, as well as uneven geographical distribution of the study areas and research institutes. However, more studies integrating social dimensions across the three components of risk analysis are needed. Especially in the risk assessment stage, social or community-level interactions lack solid establishment. This has led to a limited number of scientifically documented papers that combine risk analysis and primary interactions at the social community level. Social actors' involvement in IAS risk analysis varies, with managers, scientists, citizens, and professional nature users being the most frequent participants. Furthermore, the methods used and the data collected differ across the components. The study shows the challenges and the potential of the existing body of literature to contribute to the IAS risk assessment. In particular, the increase of public awareness and the involvement of different social groups, including often underrepresented groups such as women, indigenous communities, and low-income people, in risk analysis and management deliberation can lead to better outcomes. This inclusion is crucial for addressing differing concerns and fostering trust between stakeholders and managers.

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Introduction

Social dimensions are crucial for understanding biological invasions. In fact, invasive alien species (IAS) are, by definition, a human activities-related problem, threatening biodiversity, the economy, and human health (IAS regulation- Regulation (EU) 1143/2014, Roy et al. 2023). Furthermore, human activities are central to their introduction, spread, and management (Pyšek et al. 2020; Shackleton et al. 2019). Social dimensions include social relationships, social communities, cultures, traditions, beliefs, and values, which are essential to understand IAS as a challenge (Jarić et al. 2025, Table 1). Yet, these aspects have often been overlooked in the assessment of IAS threats and management strategies (Shackleton et al. 2019).

Since the early 2000s, risk analysis has proven effective in supporting biosecurity measures to prevent the introduction and facilitate the eradication and control of IAS (Stohlgren & Schnase 2006; Moshobane et al. 2019; Vilizzi et al. 2021). Risk analysis is a systematic process that encompasses three successive components: risk assessment, risk management, and risk communication (Liu et al. 2011a, b, c; Kumschick et al. 2020), as exemplified by the 'Risk Analysis for Alien Taxa' (RAAT) framework (Kumschick et al. 2020). Each component focuses on a specific aspect of IAS risk evaluation and may be approached differently by risk assessors while maintaining the same structure. During risk assessment, information on the arrival, establishment, and spread of IAS is gathered to estimate invasion potential and the scale of negative impacts (cf. IAS Regulation). In the risk management step, all potential management and regulatory measures are assessed, while in risk communication the results are disseminated to provide recommendations, foster scientific debate, and enable a following reassessment (Kumschick et al. 2020).

The integration of social dimensions varies across the risk analysis components, reflecting different contexts, respectively aiming to: (i) prevent IAS arrival and providea rapid response, (ii) detect and track IAS spread, and (iii) raise public awareness and education.

Human-mediated pathways, such as trade and tourism, as well as unintentional pathways, such as contaminated equipment, are considered when

Table 1 Definition and examples of social dimensions, factors, aspects, groups, and implications related to IAS

Term	Definition	Examples
Social dimensions	Structures and processes such as values, behaviours, cultural practices, and governance systems that shape and respond to the dynamics of invasive species	Human-nature relationships, collective memory, cultural identity, societal knowledge and awareness
Social factors	Elements that influence human behaviour and decision-making related to invasive species, including societal knowledge and awareness, intra-cultural differences, sociocultural background, and values ascribed to the species	Influence on individual behaviour of cultural practices, traditional livelihoods, economic benefits, governance systems, policies, and regulations
Social aspects	Components of societies (including institutions and norms) that interact with invasive species, including cultural, economic, and governance aspects	Cultural practices, traditional livelihoods, economic benefits, governance systems, policies, and regulations
Social actors	Distinct groups of people with shared characteristics, interests, or values that interact with invasive species, such as Indigenous Peoples, small-holders, and traditional knowledge holders	Recreational users, commercial operators, conservationists
Social implications	Consequences of invasive species on human well-being, livelihoods, and cultural heritage, such as impacts on food security, human health, economic development, and cultural identity	Impacts on local communities, indigenous cultures, and socioeconomic systems

assessing the likelihood of IAS entry (i.e. risk assessment) (Kumschick et al. 2020), thus incorporating social aspects.

When an IAS establishes in a new area, the evaluation of management options, including the development of plans, financial resource assessment, and prioritization of interventions (i.e. risk management), must consider the social perception and benefits of IAS (Wilson et al. 2017; Kumschick et al. 2020). However, the inclusion of benefits is influenced by stakeholders' agendas and decision-makers' priorities (Kumschick et al. 2012; Woodford et al. 2017).

Finally, risk communication conveys findings to stakeholders, helping them adapt to changing circumstances (Kumschick et al. 2020).

Over the last decade, the social dimensions of IAS invasions have gained attention for their role in understanding and managing biological invasions (Head et al. 2015; Estévez et al. 2015; Kueffer and Kull 2017; Bacher et al. 2018; Kapitza et al. 2019). However, traditional approaches to address the social implications of IAS management have been criticized for their lack of effectiveness and democratic legitimacy, due to the frequent use of top-down approaches and the affected communities' exclusion from participation (Crowley et al. 2017).

This calls for more deliberative, participatory approaches that incorporate social actors in risk assessments for a more contextual and holistic understanding of the IAS problems and implement socially acceptable and effective measures. Such approaches can identify further risks, that are not apparent through technical analysis alone, thus ensuring equity by including the perspectives of marginalized and underprivileged groups, while enhancing the effectiveness of management strategies by aligning them with social actors' needs and concerns (Graham et al. 2019), considering social and cultural acceptability of the measures to be taken. Hence, a common and shared understanding of how social dimension is or can be included into risk analysis is still needed; involving social groups in risk analysis can guarantee public support and increase the likelihood of successful management.

If public engagement is lacking, opposition to management actions can arise, as shown e.g. by the halted eradication of the American grey squirrel in Italy (Bertolino and Genovesi 2003) and by the UK Ruddy duck management challenges (Rotherham and Lambert 2012). Conversely, stakeholder participation can lead to successful outcomes, as seen in New Zealand marine IAS pathway management plan (Cunningham 2019).

The primary aim of this review is to analyse the existing evidence on the integration of the social dimensions of IAS in the reviewed literature and examine how they could inform the risk analysis components.

Our specific objectives were to (1) examine trends of social dimensions in IAS studies, and (2) investigate aspects of social dimensions that could support risk analysis components.

Particularly to address the second objective, our systematic literature review considers studies within and beyond formal risk analysis procedures. In fact, regardless of the presence of a risk framework in the original study, all the articles have been reclassified into at least one of three components of IAS risk analysis framework. This has been done to make explicit the potential of the existing body of literature targeting the social dimension of IAS in supporting all the phases of risk analysis, and thus biosecurity measures.

Methods

General approach

The review focuses on peer-reviewed articles published in international and national scientific journals and studies from national reports. Grey literature and online media, e.g. news, short online stories and local planning documents, are also part of this review. Grey literature was considered to provide firsthand accounts that may not be published in traditional academic sources.

Articles on peer-reviewed journals in English were considered up to the 24th of April 2024. Protocol PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) (Page et al 2021) was used for our systematic review on peer-reviewed, grey and online data sources. The flow diagram presenting the key steps of the methodology and the selection process is shown in Fig. 1. The paper selection was performed in two main steps: abstract and full-text screenings (Steps 2 and 3 in Fig. 1). After keywords identification and publication search (Step 1),

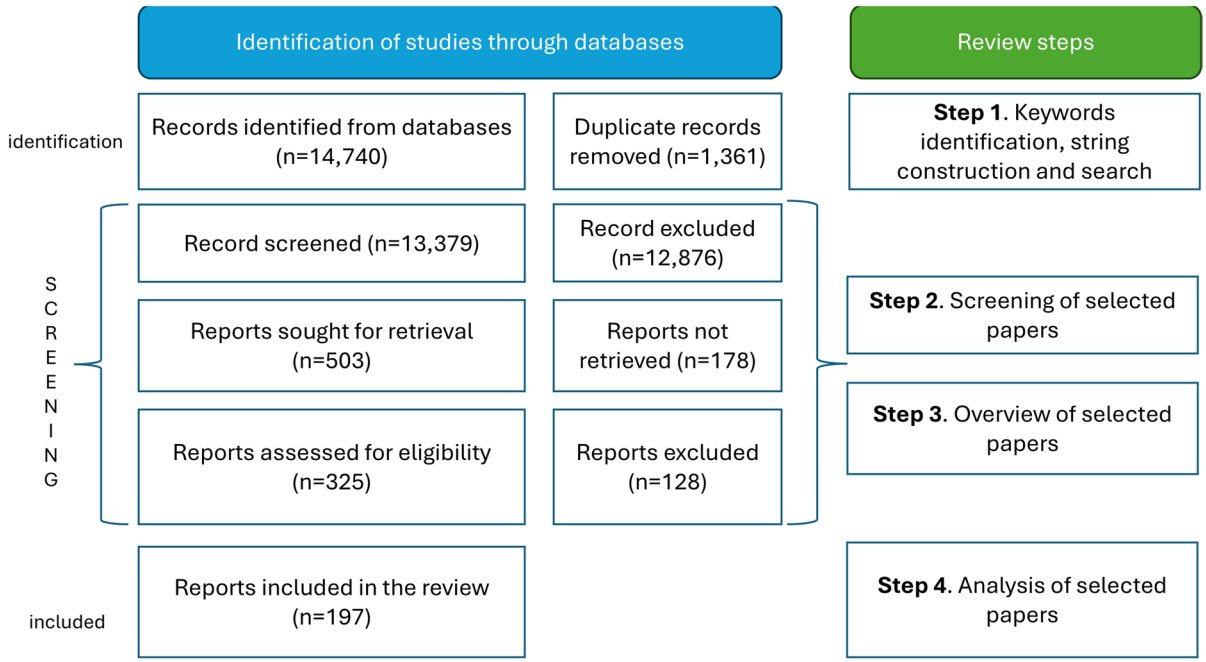

Fig. 1 PRISMA flow diagram showing the steps of the systematic review

screening of selected papers (Step 2), screening of reports selected for retrieval and assessed for eligibility (Step 3), the sample of 197 scientific papers published between 2001 and 2024 were included in the review (Step 4) (Supplementary File S2).

For online and grey literature records, a total of 181 media articles were retained after removal of duplicates, non-working online pages (i.e. accessible and secure online sources, e.g. those having a valid Hypertext Transfert Protocol (HTTP)), and the eligibility check (Figure S1, Supplementary Files S1, S3).

Data sources and review steps

Articles relevant to our study were identified in scientific journals by using keyword searches in Scopus and Web of Science databases (Supplementary File S1, Table S1). Research strings were developed using different combinations of words and Boolean operators to maximize the number of results and were adapted to each database (Table S1).

For undertaking Step 2, a study had to meet the following criteria: (1) the abstract, title or paper keywords must include any of the keywords: "social perception", "social science", "citizens", "participatory", "public", "human", "biosecurity", "invasive species", "alien species" (2) the paper focuses on, or suggests and provides evidence for incorporating the social dimension into the analysis of IAS risks.

For Step 3, the full-text of papers identified in Step 2 was screened and reviewed. Literature results were checked for duplicates and title-abstract screening was performed using the "metagear" package (Lajeunesse 2016) in R software (version 4.0.3) (Team 2020), according to the inclusion/exclusion criteria described above.

Online media and grey literature were retrieved using the Europe Media Monitor (EMM) which is a technology developed at the Joint Research Centre (JRC) of the European Commission to extract information from selected websites (e.g. national newspapers, scientific journal websites etc.). The EMM monitors routinely 17,000 web sites and processes about 450,000 publicly available pages every day in 80 languages. EMM enables research into multilingual natural language processing. The tool is accessible to European Commission officers only. For the scope of this research, online media was searched from 2014 (when EMM started) (Supplementary File S1, NewsBrief). The same English searching keywords used

in the literature review (Section Data Sources) were translated into English, Spanish, Italian, French, and Portuguese.

Considering the differences of output types between the two searches, data collected through Scopus and Web of Science databases, and EMM were analysed separately.

Data extraction

In line with the set objectives, the information from the full-text publications reviewed included: publication characteristics, paper research focus, invasive species concerned, social groups involved, methods of social involvement and type of information gathered in the study (Step 4). For online media records identified through EMM, articles were categorised according to the three components of risk analysis by identifying characteristics and features that inform the risk context. To aid distinguishing the three risk analysis contexts during the review process, definitions from the Risk Analysis for Alien Taxa (RAAT; Kumschick et al. 2020) were used.

The data extracted from the review were organised into categories (Table 2, Supplementary File S2). Six categories related to publication details (objective 1): article Digital Object Identifier (DOI), journal title, publication year, authorship, institutional affiliations, journal classification, country, and spatial scale (Table 2). Two categories related to IAS characteristics (objective 1): habitat and taxonomic classification (Table 2). The data collection was encoded into six categories (objective 2): economic factors, and perceptions and behaviours (attitudes, perceptions, values, preferences) concerning the arrival, establishment, and spread of IAS, IAS knowledge, recorded IAS occurrences, and other relevant information (Table 2, Supplementary File S1). Subsequent coding focused on social actors and components of risk analysis (objective 2). The term ‘social actors’ was chosen over ‘stakeholders’ to highlight the emphasis on values and behaviours in relation to IAS, beyond economic dimensions. Information was collected on the groups involved in the studies (e.g., citizens, recreational nature users, professional nature users, scientists, experts, etc.) and the methods through which they were integrated into any stage of the risk analysis (Table 2) (objective 2).

To analyse trends in the social dimensions of IAS studies, the spatial scale of the studies was used to cluster the papers into three groups (objective 1): "EU" for studies within the European Union, including outermost regions but excluding Russia, "Non-EU" for studies in those areas that are geographically European regions but not European Union (i.e., Serbia, Turkey, Albania, etc.…), and "global" for studies with location outside the EU and Non-EU regions (i.e., Australia, USA). By categorizing studies into these groups, we aimed to explore potential regional patterns and differences in IAS research, with particular focus on the European context. The distinction between EU and Non- EU was made to account for the research priorities of the European Union, allowing for a better understanding of research trends in this geographical area.

Finally, a cluster analysis was conducted using the hclust() function from the “stats” package in R software (version 4.0.3) (Team 2020), to identify co-occurrences of institutional affiliations in the papers and similarities in affiliation profiles (objective 1) which could indicate collaborative networks or research hotspots.

In the following paragraphs, in line with the two objectives of this review, we present an overview of how social dimensions are addressed in literature, particularly considering study area, discipline of the journal in which the research has been published, the environment and the taxa addressed. In the second part of the analysis, the studies are reclassified according to the three categories of risk analysis (risk assessment, risk management and risk communication) to understand what social actors, data, and methods are analysed in studies on IAS that incorporated the social dimension. One of the aims of reclassifying the articles has been to understand whether social actors, data and methods currently used in literature may differ according to the risk analysis phase considered in the studies.

In the subsequent discussion the contribution of the social dimension to the reviewed IAS studies and to risk analysis has been addressed before drawing the conclusions.

Results

Social dimensions in IAS studies

In our sample of 197 articles, the first research incorporating the social dimension into invasion science

Table 2 Main information extracted from the 197 studies. See Supplementary File S2

Information	Categories	Description	Reasoning for inclusion
publication	Article DOI		Unique identifier for each article, allowing for easy access and verification of sources
	Journal name		Important for assessing the credibility and impact of the research
	Year of publication		Allows for analysis of trends and patterns over time
	Journal category	Natural science, health science, social science, multidisciplinary (based on Scopus Subject area and Web of Science Categories)	Helps assess interdisciplinary engagement
	Country of the study and spatial scale	European Union (EU), Non- EU, Global	Reveals regional biases in research effort and approach, and allows for comparison of IAS management strategies across different geographic contexts
IAS features	Environment	Terrestrial, marine, freshwater, not specified	Social perceptions and management approaches often differ between terrestrial vs. aquatic invasions, and understanding these differences is crucial for effective IAS management
	Taxonomy	Invertebrates, fish, amphibians, reptiles, birds, mammals, plants, algae, fungi, others, not specified	Different taxonomic groups have varying levels of charisma and visibility, influencing public perceptions and management priorities
Data collection	Economic	Willingness-to-pay, costs per household, perceptions about prevention costs, socio-economic benefits of different management plans, health costs	Economic data is essential for assessing the feasibility and effectiveness of IAS management strategies
	Perceptions and behaviours linked to IAS arrival, establishment and spread,	Risk behaviours relating to pet releases, gardening choices, behaviours towards IAS and native hosts, boasting behaviour	Understanding human behaviours and perceptions is critical for developing effective IAS prevention and management strategies
	knowledge of IAS	Awareness of invasion topics, biosecurity measures	Assessing knowledge and awareness of IAS is essential for identifying gaps in public understanding and informing education and outreach efforts
	IAS occurrences		Provides insight into the prevalence and distribution of IAS, informing management priorities and strategies
	Other	Visions of nature and perceptions of IAS, goals and objectives of different management programs, ideas on how to improve biosecurity practices, suggestions about management and communication	Captures a range of additional information that can inform IAS management and policy, including stakeholder perspectives and emerging issues

Table 2 (continued)

Information	Categories		Description	Reasoning for inclusion
Social dimension	Groups involved		Citizens, recreational nature users, professionals, NGOs etc.…	Identifies the diverse range of actors involved in IAS management, highlighting the need for collaborative and inclusive approaches
	Data collected from groups involved			Allows for analysis of the social and cultural contexts of IAS management, and the development of targeted outreach and engagement strategies
	Classification to inform risk analysis components		Risk assessment, risk management, risk communication	Provides a framework for assessing and managing IAS risks, and for developing effective communication strategies and promote proactive management

was published in 2001 (Johnson et al. 2001) when recreational boaters were interviewed about their behaviour to assist a risk assessment for zebra mussel (*Dreissena polymorpha*) dispersal in the Lake St Clair (Michigan, USA). Between 2001 and 2005, less than one study incorporating social dimension was published globally per year (Fig. 2). Thereafter, the number of publications increased over the years, with faster growth in some years (e.g. 2011 and 2019) (Fig. 2). Studies were undertaken in specific locations at national scale, with most reviews focusing on global regions, that showed a general upward trend from 2001 to 2023 (Fig. 2). The studies in EU countries increased over time starting from 2006 (Fig. 2). The first study in the EU examining the perception of IAS and other environmental problems on the islands of Mallorca, Sardinia, and Crete (Bardsley and Edwards-Jones 2007). In online media, half of the articles examined focus on the context of risk management across countries, followed by risk communication (59) and risk assessment (32) (Figure S2). Articles with information relevant to risk assessment were reported in 13 out of 32 countries (Figure S2). The United States had the highest number of articles (43) addressing all three components of risk analysis, followed by Spain, Italy, and the United Kingdom (Figure S2).

The cluster analysis of co-occurring affiliations in the reviewed papers revealed the structure of the affiliation network and the characteristics of each cluster (Table S2). Out of the top 10 institutions with a weighted frequency ≥ 12 (Table S2), only one is in Europe, i.e. the University of Exeter, while the majority are situated outside Europe, primarily in the USA (e.g., Colorado State University, State University System of Florida) and Australia (e.g., Commonwealth Scientific & Industrial Research Organisation (CSIRO), University of Adelaide). To this end, the cross-tabular results (Table S3) show that while European authors conduct the majority of their research within the EU (i.e. 202 studies, Table S3). There is also a significant global presence in research studies, particularly from authors in North America (i.e. 222 studies, Table S3) and Oceania (i.e. 21 studies within EU and 92 global, Table S3).

The 197 reviewed articles were primarily published in journals with a focus on social science disciplines (59%, Figure S3). Specifically, this represents 52% of the publications from the EU, 42% from

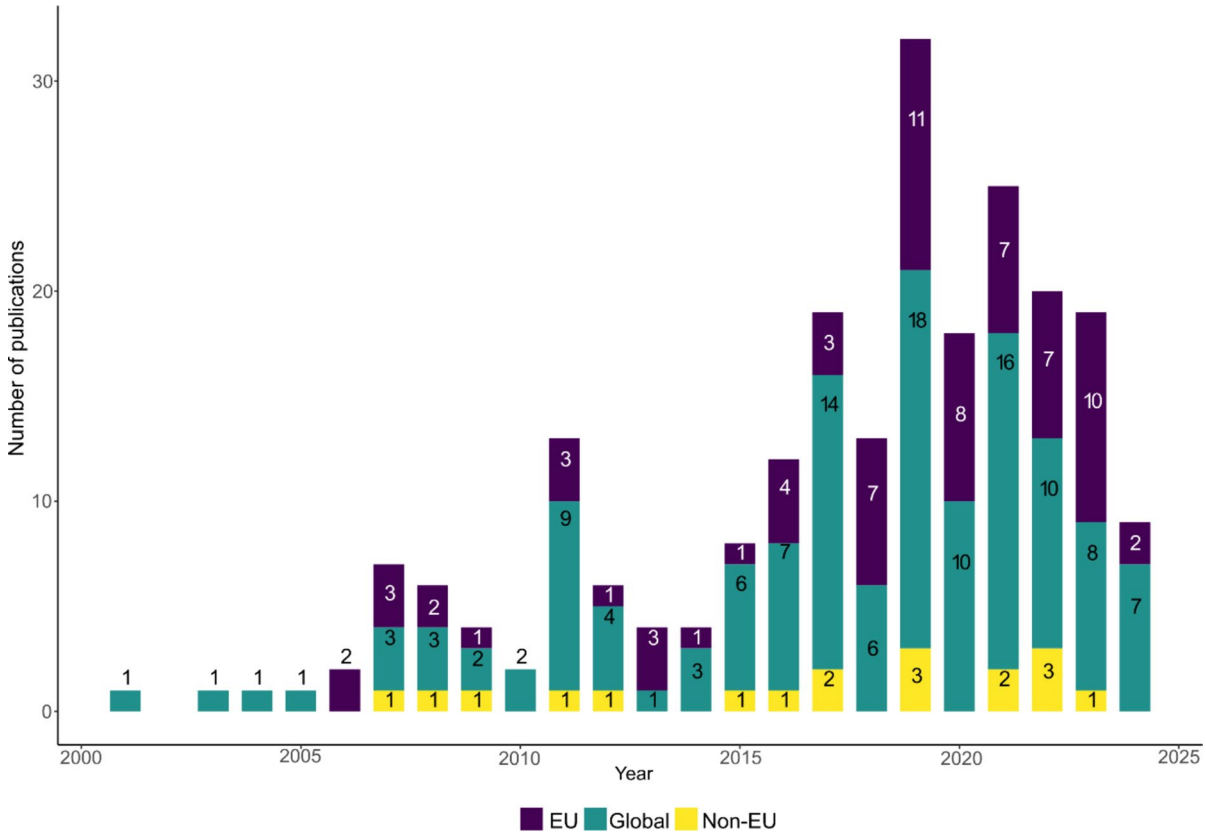

Fig. 2 Number of publications over time grouped by spatial extent of the study area in EU (within the European Union), Non- EU (areas that are geographically European regions but not part of the European Union) and Global (area outside EU and Non-EU regions)

Non-EU regions, and 59% of global publications (Figure S3). Additionally, 24% of the articles were multidisciplinary (e.g. 24% of EU publications, 26% from Non-EU, and 23% on a Global scale). Less than 5% of studies were published in health sciences journals, focusing e.g. on management and control strategies for the Tiger mosquito, *Aedes albopictus*, (Cerri et al. 2024) on the level of awareness of ticks in a South Australian rural community, i.e. *Amblyomma triguttatum triguttatum* (Waudby et al. 2008).

Studies published in social sciences journals are linked to the social and human aspects of IAS management, in particular highlighting: (i) public awareness and perceptions (Rodriguez-Rey et al. 2022), (ii) human-nature relationship and values (Straka et al. 2022), (iii) stakeholder engagement and participation (Williams et al. 2019), and (iv) case studies and regional focus (Poudyal et al. 2016; Savva et al. 2024).

Forty-nine percent of the studies focused on terrestrial environments, while 17% examined freshwater ecosystems, 12% investigated marine IAS, and 22% did not specify an environment (Figure S4a, Supp. File S1).

Plants and invertebrates were the most common IAS taxa in the articles, 26% and 20% respectively, plants being the most frequent group in terrestrial ecosystems, while invertebrates and fish species were more represented across freshwater and marine habitats (Fig. 3). Amphibians, algae, fungi and other taxa were mentioned occasionally, altogether in less than 10% of the studies. 17% of studies included unspecified taxa (Figure S4b, Supp. File S1).

Social dimension supporting risk analysis

To address Objective 2,

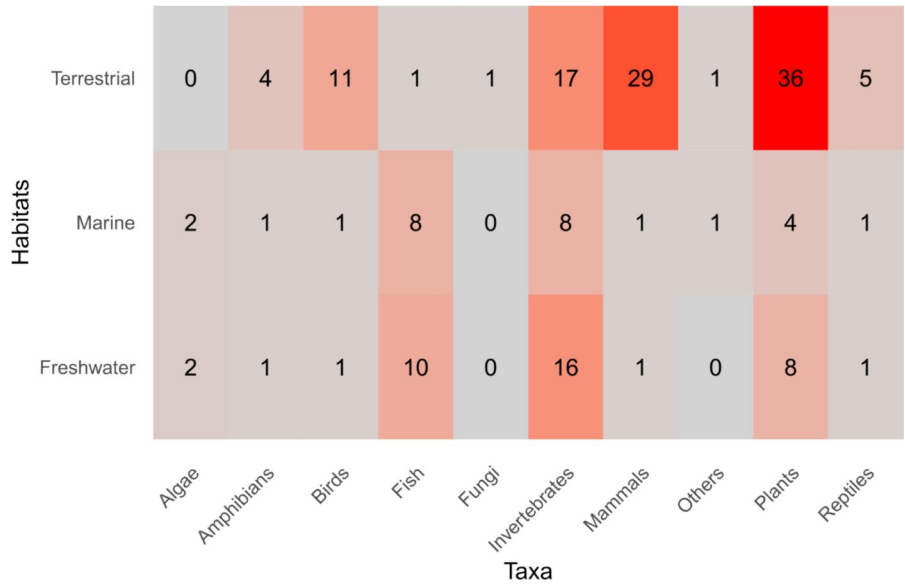

Fig. 3 Heatmap of the relationship between Habitats and Taxa in the 197 studies. Colour intensifies from grey to red with the frequency of publications of a taxon in a certain habitat. Numbers indicate the number of publications

this review identified several aspects of the social dimension: social groups involved in IAS studies, each with distinct purposes and objectives for data collection (Table 3).

Who is involved?

Overall, managers, scientists, citizens, and professional nature users, were the most frequent actors across studies while other groups, such as recreational nature users and NGOs, have a minor role (Fig. 4).

Citizens ranked amongst the most frequently involved group in the context of risk communication (34%), and similarly in risk management (24%) (Fig. 4). Managers also ranked high, especially in risk management (27%) and risk communication (23%) (Fig. 4). Scientists and experts were engaged in the context of risk assessment, participating in 30% of the studies, and also played a substantial role in risk communication (15%) and risk management (14%) (Fig. 4). On the contrary, the involvement of NGOs and recreational nature users was low across the components of risk analysis, suggesting a perception of these groups as less integrated in the studies that include a social dimension studying IAS risks. Nature professional users had some level of involvement in risk communication, at 16%, and in risk management, with a 13% participation rate (Fig. 4).

What data is collected?

The radar chart (Fig. 5) displays data on the social dimension and IAS collected in the three stages of risk analysis (Objective 2). Overall, "Perceptions & Behaviours", and "Knowledge" are consistently represented across all three stages (Fig. 5). The most collected data is from the "Perceptions & Behaviours" category, followed closely by "Knowledge" (Fig. 5). In the risk assessment stage (Fig. 5a), "IAS occurrences" and "Perceptions & Behaviours" categories receive significant attention. In contrast, the risk management stage (Fig. 5b) and risk communication stage (Fig. 5c) place greater emphasis on "Perceptions & Behaviours".

Information on "Perceptions & Behaviours" and "Knowledge" is collected across most social actors, especially for NGOs, Recreational nature users and Citizens, groups providing a strong understanding on IAS (Figure S5). On the contrary, IAS occurrences are of relevance to scientists and experts and NGOs, possibly due to their professional involvement in data collection (Figure S5).

Finally, the prevalence of "Perceptions & Behaviours" (fundamental topics of social sciences) with respect to the presence of IAS occurrences and economic data might be related to the prevalence of papers published in social science journals, which are the absolute majority of the studies reviewed (59%).

Table 3 Overview of the social dimension categories extracted from the review

Social dimension	Description	Examples
Social actors	Citizens	E.g., local community, indigenous groups, lay persons
	Recreational nature users and consumers	Nature users and tourists, recreational fishers, park visitors, pet owners, aquarium hobbyists and domestic gardeners
	Professional nature users	Professionals and representatives of sectors/ industries such as agriculture, aquaculture, fishing, industries unions and associations, business owners, landowners, public zoos and aquaria
	Scientists and experts	Natural and social scientists, including academics and researchers as well as other experts, research institutions, universities, regional and local experts and experts from educational or conservation organisations
	Managers	Local managers, and governmental institutions, e.g., policy makers, federal, state and local environmental agencies, land managers, site stewards, foresters and park workers
	NGOs	Non-governmental and non-profit organisations
	Others	Not specified groups as well as other groups not fitting the aforementioned categories, e.g., online public, religious leaders and practitioners, political parties, media, school teachers and students, unspecified restoration projects
Data collected	Economic	Data on costs, benefits, and economic impacts of IAS
	Attitudes, perceptions, values, preferences	Public opinions, surveys, and stakeholder feedback on IAS
	Behaviours linked to IAS arrival, establishment or spread	Human activities that contribute to the introduction and spread of IAS
	Knowledge of IAS topics, awareness	Levels of understanding and awareness of IAS among different social groups
	IAS occurrences	records of IAS sightings, distribution, and outbreaks
	Other	Demographic data, social network analysis, and other types of data not specified above
Methods	Methods of communication with social groups,	Questionnaire (face-to-face, mail and phone questionnaires), interview (individual as well as semi-structured interviews, in-person and via phone), participation workshop (including meetings and courses), campaign event (including games, simulation games, exhibitions, open air events, hands-on activities, simple experiments), dataset (including governmental datasets, databases, lists inventories of IAS, archival materials), media (normal and social media), other (e.g. website with information on IAS or contained in an email, postcards, direct observations by experts, field data collection, lesson plans, curricula, not specified methods)

How are data collected?

Social engagement methods varied across studies (Fig. 6). All eight methods identified in the review (i.e., questionnaires, interviews, participation workshops, public comments, campaign events, public datasets, media, and other) were used in the studies

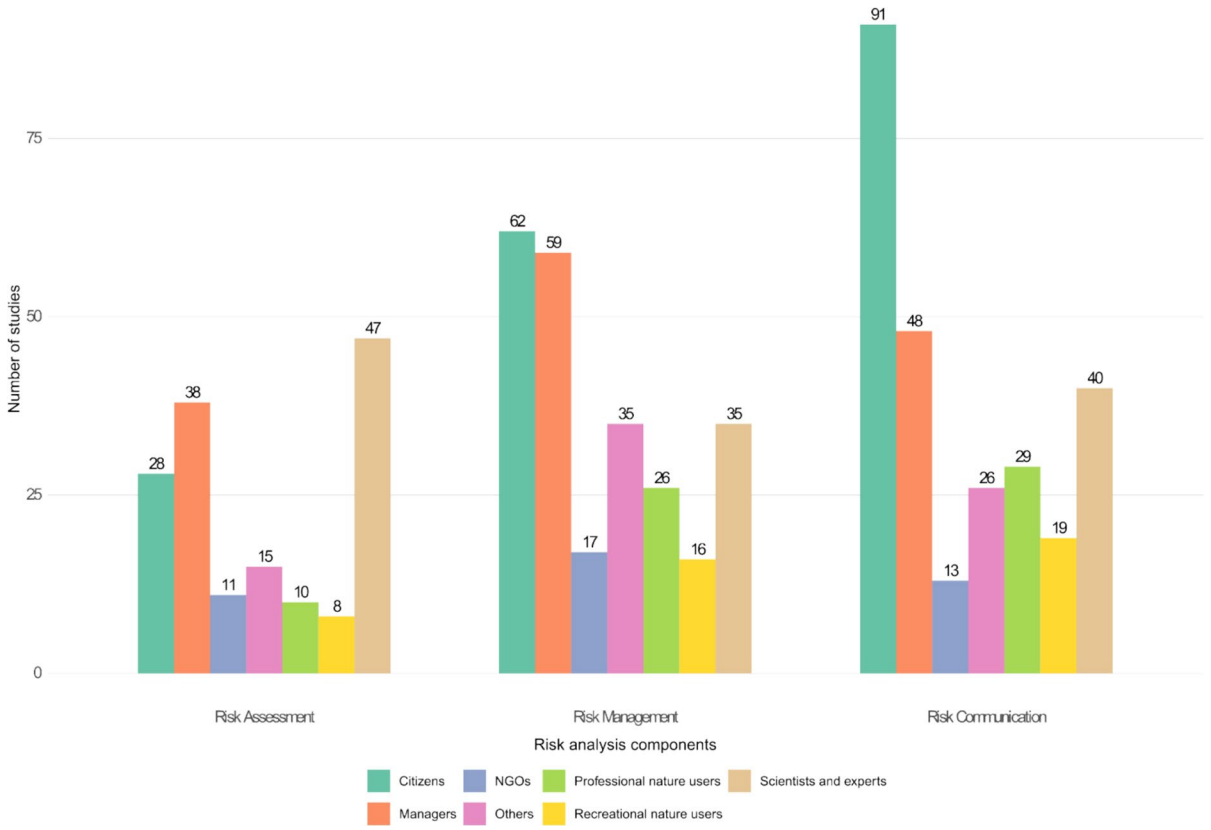

Fig. 4 Bar plots showing the number of studies in which different social groups participated in risk assessment, management and communication contexts. Studies do not add up to 197 because are classified under multiple risk analysis components

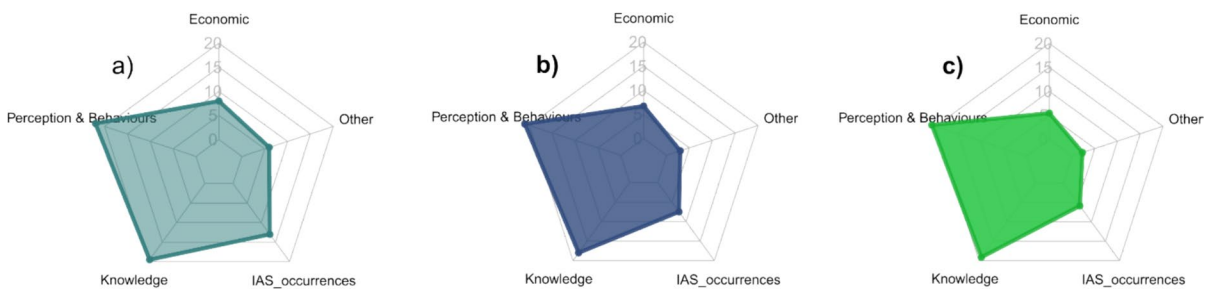

Fig. 5 Data collected across studies with context relevant for risk analysis components, i.e. **a** risk assessment, **b** risk management, and **c** risk communication. See Table 3 for variables names in each of the risk categories

grouped into risk assessment and communication (Fig. 6).

"Other" methods were the most frequent approach for engaging social actors (55%) (Fig. 6) in those studies having a context for risk assessment; for example, by providing recommendations for changes to legislation and monitoring methods that could be shared with social actors and stakeholders (e.g. online marketplaces, pet trade associations), conservation organizations (Lassaline et al. 2023), by following deliberative multi-criteria evaluations (Liu et al. 2011a, b, c), or by discussing theoretical approaches to managing biological invasions (e.g. resist-accept-direct, Dunham et al. (2022)).

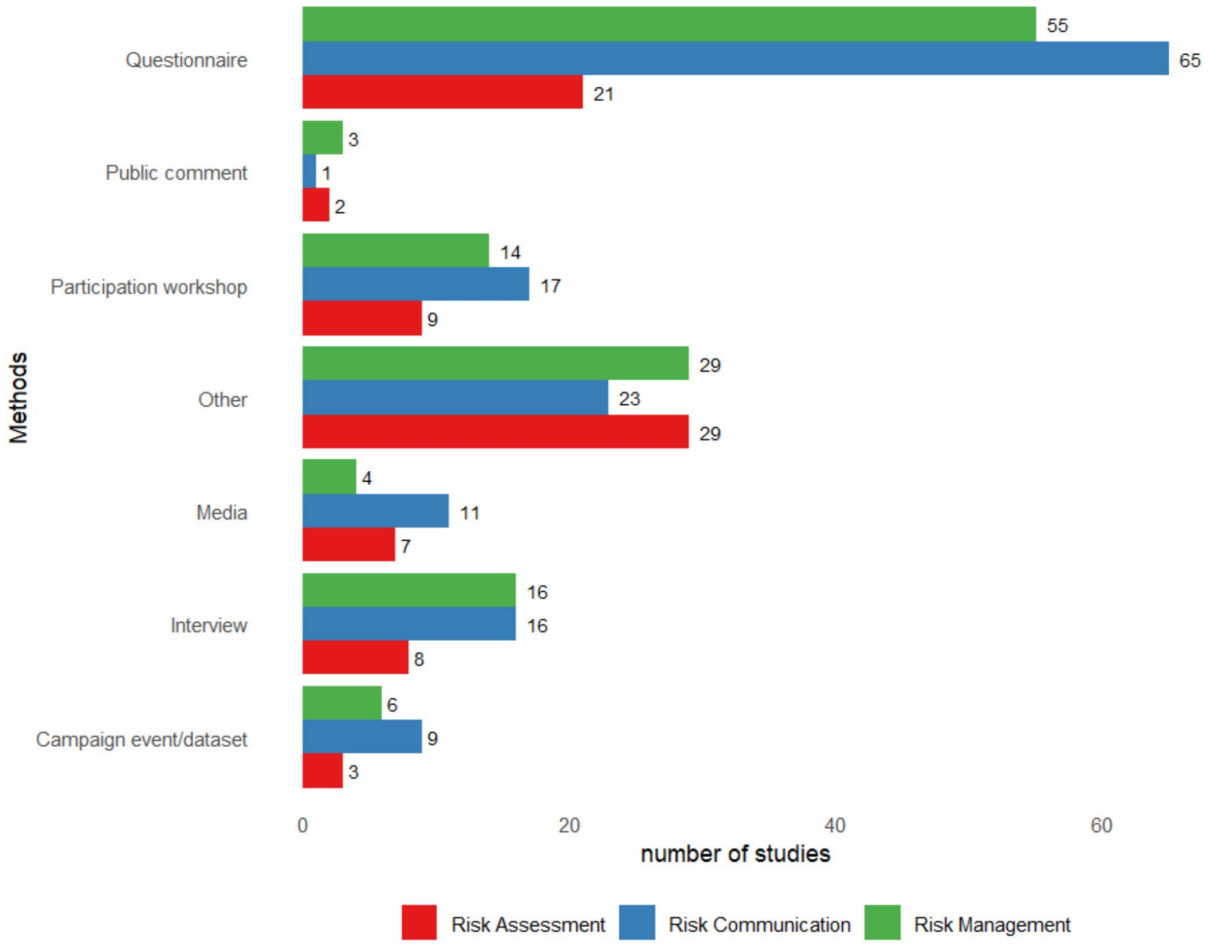

Fig. 6 Number of studies across social engagement methods and risk assessment (53 studies), management (93 studies) and communication (105 studies). The studies do not add up to 197 because they are classified under multiple risk analysis components

The most frequently employed method was using questionnaires (62%) (Fig. 6) for studies on risk communication.

In the risk management category of studies, social actors were involved through almost all methods, and the most employed tools were questionnaires (60%) and "Other" methods (32%) (Fig. 6). Additionally, participation workshops were also used frequently in risk management (15%), risk communication (16%), and risk assessment (17%) (Fig. 6). Conversely, interviews were employed in 17% of the cases for risk management, 15% for risk assessment and 15% for risk communication. Campaign events and datasets were predominantly used as methods for involvement in risk communication actions (9%), while used less frequently for risk management (6%) and risk assessment (5%) (Fig. 6). The use of media followed a similar trend, and relatively common method for risk communication (11%) but less prevalent in risk management (4%) (Fig. 6).

Discussion

This study investigated how the social dimensions are incorporated in risk analysis in the reviewed literature. In addition, it analyses how the current research on IAS can inform risk analysis components, with a focus on the social dimensions that could support and enhance these components. Despite the growing emphasis on stakeholders and public participation in addressing invasive alien species issues, social

involvement in risk analysis of IAS is a recent development and still lacks a solid establishment. Out of the 14,740 papers we collected with a context in risk analysis and IAS, 197 selected studies involved social groups. This section discusses the trends (objective 1) and social dimensions (objective 2) across various components of risk analysis, with the aim of understanding how the existing literature and the identified knowledge gaps can inform and improve risk analysis and future research on IAS, particularly in terms of integrating social dimensions into these efforts.

Trends of social dimensions across risk analysis components

The recognition of social dimensions in invasion science is gaining momentum worldwide. Our study on 197 publications showed a progressive increase (Fig. 2) in integrating social dimensions in IAS study for mitigating potential conflicts, particularly as IAS management becomes more prevalent and ambitious (Glen et al. 2013; Russell et al. 2015).

There could be several structural reasons for having a few scientifically documented papers combining risk analysis and primary interactions at the social community level (Kalnicky et al. 2014). For example, the lack of widely accepted standardized frameworks and tools for integrating risk analysis and social/community-level interactions creates a hindrance to researchers in developing and applying new approaches (Liu et al. 2011a, b, c; Caceres-Escobar et al. 2019). Data availability and accessibility represent another issue: risk analysis often requires large datasets, which may not be available or accessible for social/community-level studies (Ellis et al. 2023; Chen et al. 2024). Online media articles, predominantly from the United States, focused on risk management, highlighting the need for comprehensive risk analysis, which includes risk assessment, risk management, and risk communication. The media influence on public perception and the framing of IAS issues (Lioy et al. 2019) emphasises the importance of including diverse social perspectives in risk analysis to ensure that ethical, social, economic, and functional concerns are not overlooked (Green and Rohan 2012).

Geographic scope analysis indicates a general increase in the number of articles outside Europe from 2001 to 2023, while studies within the EU territory (our area of interest) have been growing since 2006, particularly in the last five years.

European authors have primarily conducted research within the EU, while North American and Oceanian authors have maintained a significant global presence. This leadership may correlate with broader patterns of trade, development, and the historical spread of invasive taxa and habitats. Indeed, these regions have been focal points for the introduction of IAS through centuries of global trade and economic development (Roy et al. 2023).

As a result, this geographic distribution of research reflects the socio-political contexts within which IAS management occurs and the need for inclusive public engagement to prevent and mitigate conflicts arising from differing values, perceptions, and preferences towards IAS (e.g., Ngorima and Shackleton 2019; García-Llorente et al. 2008). Moreover, it raises the question of whether current literature is focusing primarily on assessments for species and habitats where ex-post action can yield tangible benefits, while suggesting a greater focus on risk activities towards ex-ante measures.

The majority of articles (59%) have been published in social science journals. For example, these studies (i) explored how gender, race, and risk perception influence attitudes towards invasive species, as in the case of weed management in rural California (Norgaard 2007); (ii) gathered g stakeholders' perspectives on the impact of invasive species (e.g. lionfish) and their willingness to consume them as a form of control (del Carmen Carrillo-Flota and Aguilar-Perera 2017), (iii) used social network analysis to investigate the relationships between stakeholders involved in invasive species management and identify potential roles for communities in sustainable management (Omondiagbe et al. 2017), (iv) studied media coverage on invasive species management to understand how media frame the issue and influences public perception. (Lioy et al. 2019), (v) used experimental design to test how different risk communication strategies influence public understanding of invasive species science (Warner and Kinslow 2013), and (vi) used an experimental design to test the effectiveness of different message frames in promoting support for feral dog eradication (Contreras-Abarca and Simonetti 2023). Less than 5% of studies appeared in health sciences journals, thus suggesting a potential barrier to interdisciplinary knowledge exchange,

which is crucial for addressing the complexity of IAS problems (Abrahams et al. 2019). To bridge this gap, future research should investigate these links considering IAS impacts across different field of study, and possibly in an interdisciplinary way, with a view to establishing shared methodologies that can favour the inclusion of the social dimension in IAS risk assessment.

Research on habitat focus reveals that 49% of studies concentrated on terrestrial environments, with aquatic environments such as freshwater and marine systems being less represented (17% and 12% respectively). Plants and invertebrates emerged as the most common IAS groups studied, with plants dominating terrestrial habitats and invertebrates and fish the freshwater and marine environments. This bias towards terrestrial studies suggests a need to increase research efforts in aquatic habitats, where invasive species have significant impacts on biodiversity and ecosystem services (Campbell and Hewitt 2018; Katsanevakis et al. 2014).

Social actors

The involvement of social actors in risk analysis varies across different social groups and risk components. Managers, scientists, citizens, and professional nature users are the most frequently involved in risk analysis. However, differences in methodologies adopted by risk analysts raise questions about the need for a standardized methodology for social actor inclusion in risk analysis of IAS.

Managers are essential to managing risks, and are often targeted in the risk assessment and management stage, which received the largest contribution from social groups in risk analysis. The significant participation of professional nature users, such as fishers, tourism operators, and landowners, as well as citizens in risk analysis, suggests that these groups are recognized as vital for controlling IAS.

The expectation that citizens' involvement would be the highest in risk communication is justified, as increasing public awareness of IAS is key, given their direct impact on local communities. This, in turn, may generate more support for management efforts. Research has highlighted the importance of considering diverse perspectives, such as those of land managers, indigenous groups, and local communities, in risk management (Norgaard 2007; Green and Rohan 2012). For instance, a study in Switzerland found that increased awareness on IAS leads to greater willingness to pay for intervention campaigns (Junge et al. 2019). Theories of conservation behaviour suggest that awareness of invasion threats can enhance public endorsement and involvement in IAS management actions (Steele and Pienaar 2021). Our findings call for a greater and diverse representation of social actors in IAS management, highlighting the importance of representation in effective decision-making. However, our own study categorization of social actors has limitations, which prevent us from drawing conclusions about the specific roles and concerns of underrepresented groups, such as women, indigenous communities, and low-income individuals, in IAS risk management. Nevertheless, the broader literature on conservation decision-making emphasizes the need for increased inclusion of these groups to foster trust and address diverse concerns (Wells et al. 2021). Therefore, we identify the inclusion of underrepresented groups in IAS management as an area warranting further attention and research, acknowledging that our data only touch on this important issue and that more work is needed to fully understand and address the complexities of representation in IAS management.

Communicating the risks about IAS to citizens is essential, but it is also important to include social actors in the other risk analysis components. Studies incorporating social actors into risk assessment have shown promising results, such as the integration of pastoral knowledge with species distribution modelling in Ethiopia (Luizza et al. 2016). Citizen science activities (i.e. using apps, workshops) can help raise awareness on IAS, collect data on IAS biology and distribution, and implement early warning (Malek et al. 2018; Sladonja and Poljuha 2018). Involving local residents in the early stages of risk analysis can help assess costs and benefits of IAS, and inform future management actions, as shown by a study in South Africa on the invasive plant, *Acacia dealbata* (Ngorima and Shackleton 2019).

Risk management may benefit from direct citizen involvement. In South- Eastern Australia, collective actions by landcare groups mitigated weed risks by working on collective trust, common goals, and measures of progress (Graham and Rogers 2017).

Participation in both the assessment and management of IAS is particularly significant for certain

citizen and indigenous groups who have concerns regarding environmental stewardship. A case study conducted in Brazil demonstrated the effectiveness of community engagement in establishing a management plan for IAS removal, resulting in improved livelihood for local collectors and their families (Creed et al. 2017).

Engaging professional nature users, such as farmers, fishers, tourism operators, business owners, and landowners is crucial because they work and rely on nature on a daily basis. These groups can mobilize themselves as unions or lobby groups, becoming a significant force in supporting or opposing IAS management actions. The inclusion of nature users, especially in the risk assessment phase, can provide valuable insights into IAS risks and perceptions (Vye et al. 2020). Involving diverse stakeholders can give a broad insight into different risk perceptions, attitudes, and beliefs, as demonstrated by studies in Australia (Kokotovich and Andow 2017; Van Eeden et al. 2020).

NGOs' low engagement in risk communication may be due to the fact that they do not always publish scientific articles on their projects, hence it is possible that their engagement in risk communication was undervalued in this review.

Most information exchanges in the reviewed articles related to perceptions of IAS, with stakeholders asked about their personal views and beliefs on IAS, invasions, and management actions. This was followed by knowledge and awareness on IAS, their risks and potential benefits, as well as biosecurity measures. These topics dominated the communication with all stakeholder groups, apart from recreational nature users, who were asked primarily about their behaviours (e.g., recreational fishers were asked about the adoption of invasion preventative measures through cleaning boating equipment).

The numerous studies focusing on people's perceptions, beliefs, and opinions on IAS topic are promising, as perceptions and beliefs of social actors are crucial in IAS risk analysis (Steele and Pienaar 2021; Kadykalo et al. 2021). In particular, Toomey (2023) underlined the importance of emotion, intuition, and experience in people's decision-making and how their understanding can help conservationists to create better narratives for science communication.

However, information on occurrences and economic impacts of IAS would be of high value to risk analysis. This could be improved by strengthening trust in management institutions and increasing stakeholder participation in deliberations on IAS. Towards this goal, social engagement into all stages of IAS risk analysis should be increased and the methods of social involvement should be appropriately chosen.

In our review, the methods to engage stakeholders, although variable within and between social groups, showed preference towards some methods—questionnaires, participation workshops and interviews.

Naturally, each method has both advantages and disadvantages, and is used for different objectives and scales, hence may be more suitable for specific risk analysis components. For example, questionnaires are suitable for obtaining a specific target information from a large number of participants, they are designed to be unidirectional, but also reproducible and easily transformed into quantitative information, and therefore used for risk assessment more often. Conversely, workshops allow for bidirectional information exchange, deliberation and discussions, with a more equitable power position of researchers and participants in the construction of knowledge and preferred during risk assessment and management stages. Moreover, evidence from behavioural science shows that humans are less likely to be polarised and biased in their statements and more likely to reach logical conclusions based on evidence in group settings (Mercier and Sperber 2011; Sloman and Fernbach 2018). To this end, the participation workshop is the most inclusive method of involvement in our review, as it enables a balanced participation and representation of all invited social groups, and we consider that it should be sought whenever possible. On the other hand, interviews may allow researchers to gain deeper insights on interviewees' opinions, but they are usually limited in number of participants and allow for the collection of less reproducible data with respect to questionnaires, and at an individual rather than group level as in workshops, hence they are less representative of the group dynamics. This could be an advantage, though, in those settings in which social groups' power inequalities may prevent some actors to express their opinion freely. Other methods, such as media and campaign events can be very informative, far-reaching, and might be more appropriate for risk communication. Nevertheless, Toomey (2023) emphasizes that widespread dissemination of information does not guarantee an effective communication with a significant impact. Instead, communication efforts

should be meticulously structured and rooted around the best available knowledge and evidence derived from cognitive science.

So far, our review has shown a differential inclusion of social actors when reclassifying the studies according to the risk components, while providing insights on how their inclusion in risk assessment can enhance its effectiveness. Moreover, we have briefly discussed pros and cons of different methods, briefly touching on how this could be connected with power imbalances. Both these points pose questions related to equity and inclusion of social actors, particularly the marginalised ones.

A systematic discussion of equity issues and how they are connected to IAS is beyond the scope of this review, but we believe that addressing the few following points can be relevant for this discussion and for the future development of research on IAS and their risk assessment.

Equity, as a social sciences concept, has gained attention in conservation studies as a means to address power imbalances (Friedman et al. 2018; Dawson et al. 2021). It is a multidimensional concept encompassing distribution of resources, decision-making procedures, recognition of distinct identities, and social context (Friedman et al. 2018). Including equity in research has both instrumental reasons, such as increasing the effectiveness of risk assessment (Luizza et al. 2016; Malek et al. 2018; Sladonja and Poljuha 2018; Ngorima and Shackleton 2019), and fundamental reasons, as it is considered relevant per se (Friedman et al. 2018). Further research is needed, particularly in the procedure dimension of equity, to ensure that decision-making processes involve all relevant social actors and do not perpetuate existing power dynamics, ultimately contributing to more equitable conservation outcomes (Norgaard 2007; Ludwig et al. 2001).

Conclusion

Research on socio-cultural aspects related to IAS has been expanding in recent years and this study showcased their implementation in IAS risk analysis. In line with overall recognition, our review supports the idea that conservation science, including IAS risk analysis, can benefit from the contribution of social sciences. We discussed how selected studies have explored public perceptions on IAS, reasons for obtaining public support to IAS management, conflicts surrounding IAS management, and strategies for engaging the public in IAS management. Overall, our review highlights the need for more studies integrating social dimensions across the three components of risk analysis. To this end, future studies should investigate the importance of representation in IAS risk analysis, with a focus on promoting a greater and diverse representation of social actors in conservation decision-making. While our current research highlights the need for diverse social actor involvement, the limitations of our categorization framework prevent us from drawing conclusions about the specific role of underrepresented groups in IAS management. However, the broader conservation literature suggests that the inclusion of underrepresented groups, such as indigenous communities and marginalized stakeholders, is a critical area requesting further attention. Therefore, future studies should prioritize exploring the ways in which underrepresented groups can be effectively engaged in IAS management and conservation decision-making, and examine the impacts of their inclusion on the success and equity of these efforts.

Challenges remain, regarding the differential inclusion of social actors and methods across IAS studies and the three risk analysis components, as well as on the inclusion of participatory methods and an equity framework. By acknowledging and addressing these challenges, future research can contribute to a more inclusive and equitable approach to IAS management, by prioritizing the representation and engagement of diverse social actors and promoting more effective and equitable conservation outcomes.

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Conflict Of interest The authors declare no conflicts of interest.

References

Abrahams B, Sitas N, Esler KJ (2019) Exploring the dynamics of research collaborations by mapping social networks in invasion science. J Environ Manage 229:27–37. https://doi.org/10.1016/j.jenvman.2018.06.051

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). Methods Ecol Evol 9(1):159–168

Bardsley DK, Edwards-Jones G (2007) Invasive species policy and climate change: social perceptions of environmental change in the Mediterranean. Environ Sci Policy 10:230–242. https://doi.org/10.1016/j.envsci.2006.12.002

Bertolino S, Genovesi P (2003) Spread and attempted eradication of the grey squirrel (*Sciurus carolinensis*) in Italy, and consequences for the red squirrel (*Sciurus vulgaris*) in Eurasia. Biol Conserv 109:351–358. https://doi.org/10.1016/S0006-3207(02)00161-1

Caceres-Escobar H, Kark S, Atkinson SC, Possingham HP, Davis KJ (2019) Integrating local knowledge to prioritise invasive species management. People Nat 1:220–233. https://doi.org/10.1002/pan3.27

Campbell ML, Hewitt CL (2018) Which values do non-native marine species affect? A case-study exploration of perceived values at threat in Micronesia. Front Mar Sci 5:247

Cerri J, Sciandra C, Contardo T, Bertolino S (2024) Local economic conditions affect Aedes albopictus management. EcoHealth 21(1):9–20

Chen D, Zhang L, Peng Y, Si X (2024) Exploring the association between social media and farmers' knowledge of a worldwide invasive agricultural pest, Spodoptera frugiperda (Lepidoptera: Noctuidae). Pest Manag Sci 80:678–686

Cliff N, Campbell M (2012) Perception as a tool to inform aquatic biosecurity risk assessments. Aquat Invasions 7:387–404

Contreras-Abarca R, Simonetti JA (2023) Framing messages to support feral dog eradication: Both ecocentric and anthropocentric frames work. J f Nature Conservation 72:126360

Creed JC, Junqueira ADOR, Fleury BG, Mantelatto MC, Oigman-Pszczol SS (2017) The Sun-Coral Project: the first social-environmental initiative to manage the biological invasion of Tubastraea spp in Brazil. Manag Biol Invasions 8:181

Crowley SL, Hinchliffe S, McDonald RA (2017) Conflict in invasive species management. Front Ecol Environ 15(3):133–141

Cunningham S (2019) Mitigating the threat of invasive marine species to Fiordland: New Zealand's first pathway management plan. Manage Biol Invasions 10:690–708. https://doi.org/10.3391/mbi.2019.10.4.07

Dawson NM et al (2021) The role of indigenous peoples and local communities in effective and equitable conservation. Ecol Soc. https://doi.org/10.5751/es-12625-260319

del Carmen Carrillo-Flota E, Aguilar-Perera A (2017) Stakeholder perceptions of red lionfish (Pterois volitans) as a threat to the ecosystem and its potential for human consumption in Quintana Roo, Mexico. Ocean Coast Manag 136:113–119

Dunham J, Benjamin JR, Lawrence DJ, Clifford K (2022) Resist, accept, and direct responses to biological invasions: A social–ecological perspective. Fish Manag Ecol 29:475–485

Ellis HE, Grady MJ, Jaebker LM, Bright AD, Carlisle KM (2023) A social network analysis of actors involved in wild pig (Sus scrofa) management in Missouri. Wildl Soc Bull 47:e1413

Estévez RA, Anderson CB, Pizarro JC, Burgman MA (2015) Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. Conserv Biol 29:19–30. https://doi.org/10.1111/cobi.12359

Friedman RS et al (2018) How just and just how? A systematic review of social equity in conservation research. Environ Res Lett 13(5):053001. https://doi.org/10.1088/1748-9326/aabcde

García-Llorente M, Martín-López B, González JA, Alcorlo P, Montes C (2008) Social perceptions of the impacts and benefits of invasive alien species: implications for management. Biol Conserv 141:2969–2983. https://doi.org/10.1016/j.biocon.2008.09.003

Glen AS, Atkinson R, Campbell KJ, Hagen E, Holmes ND, Keitt BS, Parkes JP, Saunders A et al (2013) Eradicating multiple invasive species on inhabited islands: the next big step in island restoration? Biol Invasions 15:2589–2603. https://doi.org/10.1007/s10530-013-0495-y

Graham S, Metcalf AL, Gill N, Niemiec R, Moreno C, Bach T, Ikutegbe V, Hallstrom L et al (2019) Opportunities for better use of collective action theory in research and governance for invasive species management. Conserv Biol 33:275–287

Graham S, Rogers S (2017) How local landholder groups collectively manage weeds in south-eastern Australia. Environ Manage 60(3):396–408

Green W, Rohan M (2012) Opposition to aerial 1080 poisoning for control of invasive mammals in New Zealand: risk perceptions and agency responses. J R Soc N Z 42:185–213. https://doi.org/10.1080/03036758.2011.556130

Head L, Atchison J, Phillips C (2015) The distinctive capacities of plants: re-thinking difference via invasive species. Trans Inst Br Geogr 40(3):399–413

Jarić I, Fernández-Llamazares Á, Molnár Z, Arbieu U, Canavan S, Correia RA, Jeschke JM (2025) Cultural integration of invasive species. Npj Biodivers 4(1):1–12

Johnson LE, Ricciardi A, Carlton JT (2001) Overland dispersal of aquatic invasive species: a risk assessment of transient recreational boating. Ecol Appl 11:1789–1799. https://doi.org/10.1890/1051-0761(2001)011[1789:ODOAIS]2.0.CO;2

Junge X, Hunziker M, Bauer N, Arnberger A, Olschewski R (2019) Invasive alien species in Switzerland: awareness and preferences of experts and the public. Environ Manage 63(1):80–93

Kadykalo AN, Cooke SJ, Young N (2021) The role of western–based scientific: indigenous and local knowledge in wildlife management and conservation. People Nat 3(3):610–626

Kalnicky EA, Brunson MW, Beard KH (2014) A social–ecological systems approach to non-native species: habituation and its effect on management of coqui frogs in Hawaii. Biol Conserv 180:187–195

Kapitza K, Zimmermann H, Martín-López B, von Wehrden H (2019) Research on the social perception of invasive species: a systematic literature review. NeoBiota 43:47–68

Katsanevakis S, Coll M, Piroddi C, Steenbeek J, Ben Rais Lasram F, Zenetos A, Cardoso AC (2014) Invading the Mediterranean Sea: biodiversity patterns shaped by human activities. Front Mar Sci 1:32

Kokotovich AE, Andow DA (2017) Exploring tensions and conflicts in invasive species management: thecase of Asian carp. Environ Sci Policy 69:105–112. https://doi.org/10.1016/j.envsci.2016.12.016

Kovacs K, Vaclavik T, Haight RG, Pang A, Cunniffe NJ, Gilligan CA, Meentemeyer RK (2011) Predicting the economic costs and property value losses attributed to sudden oak death damage in California (2010–2020). J Environ Manage 92:1292–1302. https://doi.org/10.1016/j.jenvman.2010.12.018

Kueffer C, Kull CA (2017) Non-native species and the aesthetics of nature. In: Vilà M, Hulme PE (eds) Impact of biological invasions on ecosystem services. Springer International Publishing, Cham, pp 311–324

Kumschick S, Wilson JRU, Foxcroft LC (2020) A framework to support alien species regulation: the risk analysis for alien taxa (RAAT). NeoBiota 62:213–239. https://doi.org/10.3897/neobiota.62.51031

Kumschick S, Bacher S, Dawson W, Heikkilä J, Sendek A, Pluess T, Robinson TB (2012) A conceptual framework for prioritization of invasive alien species for management according to their impact

Lajeunesse MJ (2016) Facilitating systematic reviews, data extraction and meta-analysis with the metagear package for R. Methods Ecol Evol 7:323–330

Lassaline CR, Stringham OC, Moncayo S, Toomes A, Cassey P (2023) Untangling the web: dynamics of Australia's online terrestrial invertebrate trade. Austral Entomol 62:372–387

Lioy S, Marsan A, Balduzzi A, Wauters LA, Martinoli A, Bertolino S (2019) The management of the introduced grey squirrel seen through the eyes of the media. Biol Invasions 21:3723–3733

Liu S, Hurley M, Lowell KE, Siddique ABM, Diggle A, Cook DC (2011a) An integrated decision-support approach in prioritizing risks of non-indigenous species in the face of high uncertainty. Ecol Econ 70:1924–1930. https://doi.org/10.1016/j.ecolecon.2011.05.021

Liu S, Sheppard A, Kriticos D, Cook D (2011b) Incorporating uncertainty and social values in managing invasive alienspecies: a deliberative multi-criteria evaluation approach. Biol Invasions 13:2323–2337. https://doi.org/10.1007/s10530-011-0045-4

Liu S, Sheppard A, Kriticos D, Cook D (2011c) Incorporating uncertainty and social values in managing invasive alien species: a deliberative multi-criteria evaluation approach. Biol Invasions 13:2323–2337. https://doi.org/10.1007/s10530-011-0045-4

Ludwig D, Mangel M, Haddad B (2001) Ecology, conservation, and public policy. Annu Rev Ecol Evol Syst 32(1):481–517. https://doi.org/10.1146/annurev.ecolsys.32.081501.114116

Luizza MW, Wakie T, Evangelista PH, Jarnevich CS (2016) Integrating local pastoral knowledge, participatory mapping and species distribution modeling for risk assessment of invasive rubber vine (Cryptostegia grandiflora) in Ethiopia's Afar region. Ecol Soci 21(1):22

Malek R, Tattoni C, Ciolli M, Corradini S, Andreis D, Ibrahim A, Mazzoni V, Eriksson A, Anfora G (2018) Coupling traditional monitoring and citizen science to disentangle the invasion of *Halyomorpha halys*. ISPRS Int J Geo-Inf 7(5):171

Mercier H, Sperber D (2011) Why do humans reason? Arguments for an argumentative theory. Behav Brain Sci 34(2):57–74

McNeely JA (2013) Global efforts to address the wicked problem of invasive alien species. In: Foxcroft LC, Pyšek P, Richardson DM, Genovesi P (eds) Plant invasions in protected areas. Springer, Netherlands, Dordrecht, pp 61–71. https://doi.org/10.1007/978-94-007-7750-7_4

Moshobane MC, Mukundamago M, Adu-Acheampong S, Shackleton R (2019) Development of alien and invasive taxa lists for regulation of biological invasions in South Africa. Bothalia. https://doi.org/10.4102/abc.v49i1.2361

Ngorima A, Shackleton CM (2019) Livelihood benefits and costs from an invasive alien tree (*Acacia dealbata*) to rural communities in the Eastern Cape, South Africa. J Environ Manage 229:158–165

Norgaard KM (2007) The politics of invasive weed management: gender, race, and risk perception in rural California. Rural Sociol 72:450–477. https://doi.org/10.1526/003601107781799263

Omondiagbe HA, Towns DR, Wood JK, Bollard-Breen B (2017) Stakeholders and social networks identify potential roles of communities in sustainable management of invasive species. Biol Invasions 19:3037–3049

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Moher D (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj 372:n71. https://doi.org/10.1136/bmj.n71

Poudyal NC, Bowker JM, Moore RL (2016) Understanding public knowledge and attitudes toward controlling hemlock woolly adelgid on public forests. J for 114:619–628

Pyšek P, Bacher S, Kühn I, Novoa A, Catford JA, Hulme PE, Blackburn TM (2020) MAcroecological framework for invasive aliens (MAFIA): disentangling large-scale context dependence in biological invasions. NeoBiota 62:407

Requier F, Fournier A, Rome Q Darrouzet E (2020) Science communication is needed to inform risk perception and action of stakeholders. J Environ Manage 257:109983

Ribeiro J, Carneiro I, Nuno A, Porto M, Edelaar P, Luna Á Reino L, (2021) Investigating people's perceptions of alien parakeets in urban environments. Eur J Wildl Res 67(3):45

Rodriguez-Rey M, Borrell YJ, Dopico E, Muha TP, Rolla M (2022) Understanding public perceptions toward invasive species in different parts of Europe. J Environ Plan Manag 65:2257–2275

Rotherham ID, Lambert RA (eds) (2012) Invasive and introduced plants and animals: human perceptions, attitudes and approaches to management. Routledge, London

Roy HE, Pauchard A, Stoett P, Truong TR, Bacher S, Galil BS, Vandvik V (2023) IPBES invasive alien species assessment: summary for policymakers. IPBES, Bonn

Russell JC, Innes JG, Brown PH, Byrom AE (2015) Predator-free New Zealand: conservation country. Bioscience 65:520–525. https://doi.org/10.1093/biosci/biv012

Savva I, Cai LL, Kleitou P, Hadjioannou L, Jimenez C, Karonias A, Nicolaou E, Chartosia N et al (2024) An underwater clash of spears: Public engagement in Mediterranean lionfish control efforts. Aquat Conserv Mar Freshw Ecosyst 34:e4104

Shackleton RT, Adriaens T, Brundu G, Dehnen-Schmutz K, Estévez RA, Fried J, Larson BMH, Liu S et al (2019) Stakeholder engagement in the study and management of invasive alien species. J Environ Manage 229:88–101. https://doi.org/10.1016/j.jenvman.2018.04.044

Sladonja B, Poljuha D (2018) Citizen science as a tool in biological recording—a case study of *Ailanthus altissima* (Mill.) swingle. Forests 9(1):31

Sloman S, Fernbach P (2018) Reasoning as collaboration. Am J Psychol 131(4):493–496

Stohlgren TJ, Schnase JL (2006) Risk analysis for biological hazards: what we need to know about invasive species. Risk Anal 26:163–173. https://doi.org/10.1111/j.1539-6924.2006.00707.x

Straka TM, Bach L, Klisch U, Egerer MH, Fischer LK, Kowarik I (2022) Beyond values: How emotions, anthropomorphism, beliefs and knowledge relate to the acceptability of native and non-native species management in cities. People Nat 4:1485–1499

Steele ZT, Pienaar EF (2021) Knowledge, reason and emotion: using behavioral theories to understand people's support for invasive animal management. Biol Invasions 23(11):3513–3527

Team R. C (2020) R: a language and environment for statistical computing. R Foundation for Statistical Computing. (No Title)

Toomey AH (2023) Why facts don't change minds: insights from cognitive science for the improved communication of conservation research. Biol Conserv 278:109886

Van Eeden LM, Newsome TM, Crowther MS, Dickman CR, Bruskotter J (2020) Diverse public perceptions of species' status and management align with conflicting conservation frameworks. Biol Conserv 242:108416

Vilizzi L, Copp GH, Hill JE, Adamovich B, Aislabie L, Akin D, Al-Faisal AJ, Almeida D et al (2021) A global-scale screening of non-native aquatic organisms to identify potentially invasive species under current and future climate conditions. Sci Total Environ 788:147868. https://doi.org/10.1016/j.scitotenv.2021.147868

Vye SR, Wynne-Jones S, Masterson-Algar P, Jenkins SR (2020) Exploring perceptions of marine biosecurity interventions: insights from the commercial marina sector. Mar Policy. https://doi.org/10.1016/j.marpol.2020.104027

Warner KD, Kinslow F (2013) Manipulating risk communication: value predispositions shape public understandings of invasive species science in Hawaii. Public Underst Sci 22:203–218

Waudby HP, Petit S, Weber D, Springer (2008) Human perception and awareness of ticks in a South Australian rural community and implications for management of *Amblyomma triguttatum triguttatum*. Exp Appl Acarol 45:71–84

Wells HB, Kirobi EH, Chen CL, Winowiecki LA, Vågen TG, Ahmad MN, Dougall AJ (2021) Equity in ecosystem restoration. Restor Ecol 29(5):e13385

Williams RJ, Dunn AM, Quinn CH, Hassall C, Wiley Online Library (2019) Stakeholder discourse and opinion towards a charismatic non-native lizard species: potential invasive problem or a welcome addition? People Nat 1:152–166

Wilson JR, Panetta FD, Lindgren C (2017) Detecting and responding to alien plant incursions. Cambridge University Press. https://doi.org/10.1017/CBO9781316155318

Woodford DJ, Ivey P, Novoa A, Shackleton R, Richardson D, Weyl O, Van Wilgen B, Zengeya T (2017) Managingconflict-generating invasive species in South Africa: challenges and trade-offs. Bothalia-African Biodivers Conserv 47(2):1–11